EXHAUST EMISSION SURVEILLANCE

OF

ONTARIO IN-USE CARS

(Brief Report)

ARB-146-86-ETRD

November 1986

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1986

Ontario

Ministry
of the
Environment

E. PICHÉ, Director
Air Resources Branch

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Exhaust Emission Surveillance of Ontario In-use Cars
(Brief Report)

by

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Brief Report on Project

"Exhaust Emission Surveillance of Ontario In-Use Cars"

1. INTRODUCTION

Motor vehicles in Ontario (4.5 million) are a major source of atmospheric pollution. Gasoline-powered vehicles alone contribute an estimated 40% of hydrocarbons (HC), 70% of carbon monoxide (CO) and 30% of oxides of nitrogen (NO_x) (1978, Environment Canada).

In 1969, Ontario was the first province in Canada to initiate certification of new motor vehicles and institute a program to assess and control in-use vehicles. Certification became a federal responsibility in January 1971. Ontario continued the assessment and control programs using the Idles test (i.e. volumetric analysis for HC and CO in idle and fast idle modes). No equipment was available to produce mass-emission data.

Between 1971 and 1974, Canadian emission standards for cars were the same as in the U.S. From 1975 on (possibly until 1987) the Canadian standards remained at the 1975 level while U.S. standards became progressively more stringent (see Table 1 in Attach. 1). This discrepancy resulted in the introduction of Canada-specification cars which, when new, are five times higher than present U.S.-specification cars in HC emissions, seven times higher in CO emissions and three times higher in NO_x emissions. (Note: Recent announcements by Transport Canada indicate that by 1988 Canadian standards will again be identical to U.S. standards).

Mass-emission data of in-use Ontario cars, are not known. They are, however, suspected of being negatively affected by climatic and road conditions, tampering and 15-20% of cars with greatly excessive emission levels.

Since 1975, the U.S. emission factors were no longer applicable to Ontario emission inventories. Absence of realistic Canadian emission factors made it difficult to estimate the contribution of Ontario Light Duty (LD) vehicles to air quality, oxidants and acidic deposition problems.

2. TESTING FACILITY

In October 1976 the Ministry of Transportation and Communications (MTC) announced it would install a chassis dynamometer at Downsview and test vehicles for fuel economy. The Ministry of the Environment (MOE) proposed that if it provided sampling and analytical equipment the facility could be developed into a proper mass-emission test centre, capable of carrying out federal constant-volume sampling (CVS-2) procedure. Between February 1977 and July 1979 the facility was designed and constructed by MTC, Ministry of Energy, Ministry of Government Services and MOE. Test time usage has been tentatively split between MTC and MOE in a 60/40 ratio, providing MOE with an opportunity to test two cars per week (approximately 85-90 cars per year). (Note: Replacement cost of this test facility is estimated at between $700,000 and $900,000).

The MOE contribution consisted of: Constant Volume Sampler - CVS, analytical console with two CO analyzers, two HC analyzers, NO_x and CO_2 analyzers, a recorder, calibration gases (over 80 mixtures), regulators, calibration equipment (laminar flow element, critical flow orifice, NO_x generator, gas dividers, precise manometers etc.). MOE also provided the services of an analyst (until 1982 when the position was annexed by MTC as regular staff), partial

service of an instrument technician and covered expenses of calibration gases, demurrage, instrument maintenance and replacement and the quality assurance program.

Funding for the MOE contribution came from the Vehicle Emission Unit (VEU) regular budget and special funds contributed by MOE's acid rain and reactive hydrocarbons projects. Average yearly funding, including a contract technician, was between $40,000 and 50,000. There has never been a separate budget for this test program.

3. U.S., CANADA AND ONTARIO TEST PROGRAMS

The Environmental Protection Agency has been conducting Emission Factors Programs in the U.S. since 1968, and testing between 400-2200 cars per year. All tests since 1971 are mass-emission tests using CVS-1 (2-bag) or CVS-2 (3-bag) procedures. Environment Canada has been testing 40-50 new cars per year (mostly at the 6000 km point using CVS-2). Four to six cars are tested several times while accumulating up to 80,000 km.

Spot-checking cars in Ontario began in 1969. Before it was phased out in 1982 (due to lack of man-power) more than 103,000 vehicles were tested, most of them using the Idles test.

The VEU established a mass-emission test program in 1979, later called: "Exhaust Emission Surveillance of Ontario In-Use Cars".

4. TEST PROGRAM OBJECTIVES

(a) To assess exhaust emissions (HC, CO, NO_x) from 200 in-use cars representing the Ontario car population as of mid-1982.

(b) To provide the basis for Ontario automotive emissions control strategies and criteria for their evaluation.

(c) To establish a data base for generating representative emission factors for Ontario inventories and air quality modelling (acid rain, oxidants).

(d) To estimate compliance of Ontario cars with provincial emission criteria and Canadian standards.

(e) To assess average emissions from so called "excessive emitters".

(f) To establish correlation between cold-start (FTP-75) and hot-start (MFTP-75) tests, to provide a faster and cheaper test method.

(g) To establish average fuel consumption data needed for Ontario emission inventories.

5. TEST PROGRAM DESIGN

A sample of 200 cars representing the Ontario car population as of mid-1982 was defined by manufacturers, model years, car and engine sizes and mileage ranges.

Ninety per cent of cars tested are privately owned, recruited from the Greater Metro Area and tested in "as-received" condition (original fuel and tires, no prior tuning). Cars with diesel engines, faulty brakes, leaky exhaust systems, serious smoke problems, worn-out or damaged tires, or with unusually low or high odometer readings are excluded. Vehicle owners are requested to fill out a questionnaire concerning use and maintenance. Compensation for making the vehicle available for the 1½ days is between $40 and $90. A special insurance policy covers cars while in MOE care.

6. TEST VEHICLE SELECTION AND ACQUISITION

A target list of 200 cars representative of the Ontario car population has been compiled using data from MTC on Ontario car populations, R.L. Polk & Company on yearly new car registrations (by manufacturers, models) and MOE spot-checking programs (by model years and popularity of engine families).

The sample size was established after consulting statistical procedures, sample sizes used by EPA in different years and cities and after considering the testing capacity (about 85 cars per year) available to MOE.

Using the target list, a contract technician searches for suitable cars on large parking lots in the Metro area. (e.g. shopping plazas, companies). Contacts with owners of selected vehicles are made first by letter, then by phone. A pre-inspection is performed to eliminate unsuitable or unsafe vehicles. Acceptable vehicles are collected on Wednesday or Thursday morning and returned the following afternoon after testing.

7. TEST PROCEDURES

The vehicle is first tested in idle and fast idle at Castlefield Test Centre and inspected for emission control equipment and compliance labels. Then it is transferred to the Downsview Test Centre for preconditioning (23-minute run on dyno) and soaking (usually about 18 hours at 68-86°F i.e. 20-30°C).

The following day between 9 a.m. and 10 a.m. the car is tested from cold-start using the FTP-75 (i.e. CVS-2) procedure. The vehicle is put through a loaded EPA urban test (same as specified by Environment Canada for certification of new cars), which simulates a 7.5 mile (12.1 km) suburban trip. All exhaust gases from the tail pipe(s) are diluted by ambient air inside the Constant Volume Sampler

(CVS), then proportionally sampled at a constant rate and put into plastic bags. Bag 1 (cold-start) represents the first 505 seconds of the cycle, Bag 2 (stabilized) the following 867 seconds. After an intermission of ten minutes the engine is re-started and emissions from the first 505 seconds are collected in Bag 3 (hot-start). All bags are analyzed for Total Hydrocarbons, CO, CO_2 and NO_x, and the results corrected for background concentrations in ambient air used for dilution. This completes the FTP-75 test.

After resting for 1½ to 2 hours, the car is again preconditioned by driving through a dummy FTP-75 cycle (505 plus 867 seconds). Following a ten minute intermission, a so called TWO BAG (MFTP-75) test is performed. In this case Bag 4 (hot-start) represents the first 505 seconds and Bag 5 (stabilized) represents the following 867 seconds. (Note: This shorter hot-start MFTP-75 test was developed by MOE in 1979 and included by MTC in their dynamometer procedures as "DYN-9"). The car is then returned to the owner.

8. DATA COLLECTION AND EVALUATION PROCEDURES

An on-site computer is used by MTC staff to store data on different test cycles (speed vs. time) and calculate mass-emissions and fuel consumption under standard conditions.

Vehicle data and results of cars tested under the MOE program are extracted from MTC files, coded, and statistically evaluated by an individually designed Statistical Analysis System (SAS) package using ARB electronic data processing facilities and the time-sharing option of the Downsview Computing Centre.

Each test car record consists of 46 variables. SAS makes it possible to produce simple statistics, tabulations, plots, correlations and regressions (see Attach. 2-6).

9. TEST FLEETS AND RESULTS

Between August 1979 and the end of August 1984, 390 cars were tested (at a rate of 80-84 per year, not including retests and failures).

Fleet A consists of 295 cars of 1962-1984 model year (MY) representing a Wider Ontario Sample (WOS 295).

Fleet B (a subset of Fleet A) consists of 197 cars of 1962-1982 MY that match the Target List of 200 and represent the Ontario car population as of mid-1982. (Note: In the 1962-67 MY group six cars were specified, but only three testworthy cars were found and tested. To complete Ontario Sample 200, the three cars were represented twice).

Fleet C consists of 52 police and government cars, all with high odometer readings. (These were tested at the outset of the test program in 1979-80 to establish test routines and investigate the correlation between the cold-start FTP-75 and hot-start MFTP-75 test procedures).

An additional 43 cars were tested consisting of: 2 propane-powered cars, 4 cars adjusted just prior to the test, 2 cars with incomplete results, 6 cars tested hot-start only, 16 cars that were eliminated because of unreliable results and 13 cars recently tested.

Emission results for Fleet A (arithm. means, by model year) and Fleet B are shown in Table 2 (see Attach. 6). Emissions of individual cars in Fleet A are then plotted by MY in Figs. 1 to 3 (see Attach. 2-4). Compliance of the 1975-1984 MY cars (from Fleet A) with Canadian HC and CO emission standards is illustrated by Fig. 4 (see Attach. 5). Of the 246 cars shown, 55% were found to be outside the compliance area.

10. DISCUSSION OF RESULTS (BY OBJECTIVES)

A total of 197 cars (Fleet B) matching specifications in target list 200 have been tested. The objective of assessing exhaust emissions from Ontario car population as of mid-1982 has essentially been completed.

Results of cars in Fleet B tested using FTP-75 and two shorter procedures (MFTP-75 and Idles test) establish a firm reference point (mid-1982) for evaluation of any future Ontario control strategies. The MFTP-75 test procedure is recommended as an alternative tool for evaluation of control strategy efficiencies. This objective has also been completed.

Compliance of Ontario in-use cars with **CANADA** emission standards for new LD vehicles has been estimated from Fleet B results (based on 1971-1982 models) as follows: only 26% passed all these standards (HC, CO, NO_x), 52% failed HC (alone or in combinations), 54% failed CO (alone or in combinations), 35% failed NO_x (alone or in combinations). A significant proportion (18%) failed all three standards.

Compliance with **ONTARIO** criteria (under Regulation 311 RRO, 1980) has been estimated from Fleet B results (1962-1982 MY) as follows: 48% failed one or more of the criteria (ID-HC, FI-HC, ID-CO and FI-CO); 38% failed Idle-CO (alone or in combinations), 24% failed Fast-Idle-CO (alone o. in combinations) and 17% failed one or both HC criteria. (Note: The 48% failure rate corresponds very well with a 49-52% average yearly failure rate established by MOE spotchecking programs in 1980-1982).

Excessive emitters constitute about 7% of Fleet A. (Note: Excessive emitters are cars exceeding HC and/or CO and/or NO_x limits for out-liers, i.e. Mean + 3 Standard Deviations, for their own or any previous MY group). Their actual share in Ontario car population is estimated at approximately 15% (see sampling limitations discussed in Section 5). Excessive emitters are on average six times higher in HC and four times higher in CO than cars within the 3 S.D. limits. It has been estimated that the 15% of excessive emitters are responsible for 51% of HC emissions and 41% of CO emissions from all cars in Ontario.

Correlation coefficients between corresponding phases of the full test (FTP-75) and of the shorter, hot-start test (MFTP-75, devised by MOE) are very high and significant. For Fleet A correlation coefficient $\underline{r}$ is over 0.92 for HC, 0.84 for CO, 0.92 for NO_x and 0.94 for fuel consumption. For smaller subsets of vehicles (selected by model year, manufacturer, or engine size) the correlations are even higher. This finding will make it possible in the future to replace some of the full (2-day) tests with the shorter hot-start tests, which only require approximately 2 hours of test time.

Fuel consumption figures have been established for Fleet A and subsets by model year and engine size. These results greatly improve the accuracy of emission inventories based on total fuel consumption in Ontario.

In addition to the above objectives emissions from alternate fuel vehicles (propane-powered cars) were investigated. Two identical factory-converted 1982 Mercury Cougars with 140 CID engines (without catalyst or EGR) were tested. While HC and CO emissions were comparable to gasoline-powered versions of the same engine family, NO_x emissions were more than five times higher, i.e., 7.9 vs. 1.5 G/M.

Note: Further tests of a small fleet of CNG - (compressed natural gas), propane- and methanol-powered vehicles are being performed by MTC, with the object of investigating their fuel economy (under their Transportation Energy Management Program conducted independently at Downsview). The emission results of this project supplemented by MOE's own tests will if necessary be evaluated by VEU in a separate report.

11. GENERAL OUTLOOK

As a result of federal regulations affecting 1975-1987 model years the Ontario car population will be significantly different from the U.S. population until approximately 1994 , thus precluding the use of U.S. emission factors in Ontario inventories.

Excessive emitters (estimated at 15% of all cars in Ontario) make a considerable contribution to HC and CO emissions. Investigation into their frequency and emission levels should continue.

The catalytic emission control systems, highly sensitive to tampering and misfuelling, are currently used on approximately 62% of Ontario cars. It is estimated that by 1994 90-95% of cars in Ontario will be catalyst equipped. Their natural (by age) and deliberate deactivation (by fuel-switching) should be investigated in more detail.

The Ontario government is promoting the use of alternate fuel vehicles. Research programs conducted by MTC focus on the feasibility of these fuels and on fuel economy. Evaluation of their mass emission levels, with emphasis on NO_x, is within the MOE mandate and should be expanded.

In a pilot project, the Downsview test facility may be used to investigate the reductions in HC, CO and NO_x mass emissions expected from an inspection and maintenance program should such a program be considered in Ontario.

The MOE 40% share in the MTC/MOE facility at Downsview, which has been built and maintained over the past seven years, provides MOE with a unique investigative and research tool.

12. RECOMMENDATIONS

(a) The testing capacity at Downsview Test Centre should be maintained and used over the next three years to:

- update Ontario emission factors;
- investigate excessive emitters and their contribution to total emissions from LD vehicles;
- investigate deactivation of catalytic control systems;
- perform supplementary tests to investigate emissions from alternate fuel vehicles (propane, CNG, gasohols).

(b) The possibilities of increasing the MOE testing capacity from the current 85 cold-start tests should be investigated. Additional testing capacity gained should be used for programs shown in (a) above.

13. REFERENCES

Environment Canada, "A Nationwide Inventory of Emissions of Air Contaminants (1978)". A report by Environmental Protection Service EPS 3-EP-83-10, December 1983.

Perfect N., "An Exhaust Emissions and Fuel Economy Testing Laboratory for Light Vehicles". Ontario Ministry of Transportation and Communications, Report # LAB-81-01, Research and Development Branch, May 1981.

Transport Canada, "Motor Vehicle Safety Test Methods, Chapter IV, Section 1101-Vehicle Emissions" and "Revision No. 1", Road Safety Test Methods approved Sept. 1974 and Jan. 1979, resp.

Rohac, I.Z., "Exhaust Emission Surveillance of Ontario In-Use Cars (Full Report)". Ontario Ministry of the Environment, ARB, Report in production.

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Attach.
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Relation of Canada to U.S. Emission Standards

Canada emission standards introduced in 1971 were, until end of 1974, identical to U.S. emission standards. From 1975, while the Canadian standards remained the same (i.e. at the 1975 level), the U.S. standards became progressively more stringent (see Table 1).

Table 1

Ratios of Canada/U.S. LD Vehicle Exhaust Emission Standards by Model Year

Model Year MY	THC	CO	NO_x	Note
1971-74	1.0	1.0	1.0	(1)
1975-76	1.3	1.7	1.0	(2)
1977-79	1.3	1.7	1.6	(2)
1980	4.9	3.6	1.6	(2)
1981-82	4.9	7.4	3.1	(2)
1983-87	4.9	7.4	3.1	(2)
1988-	1.0	1.0	1.0	(3) (1)

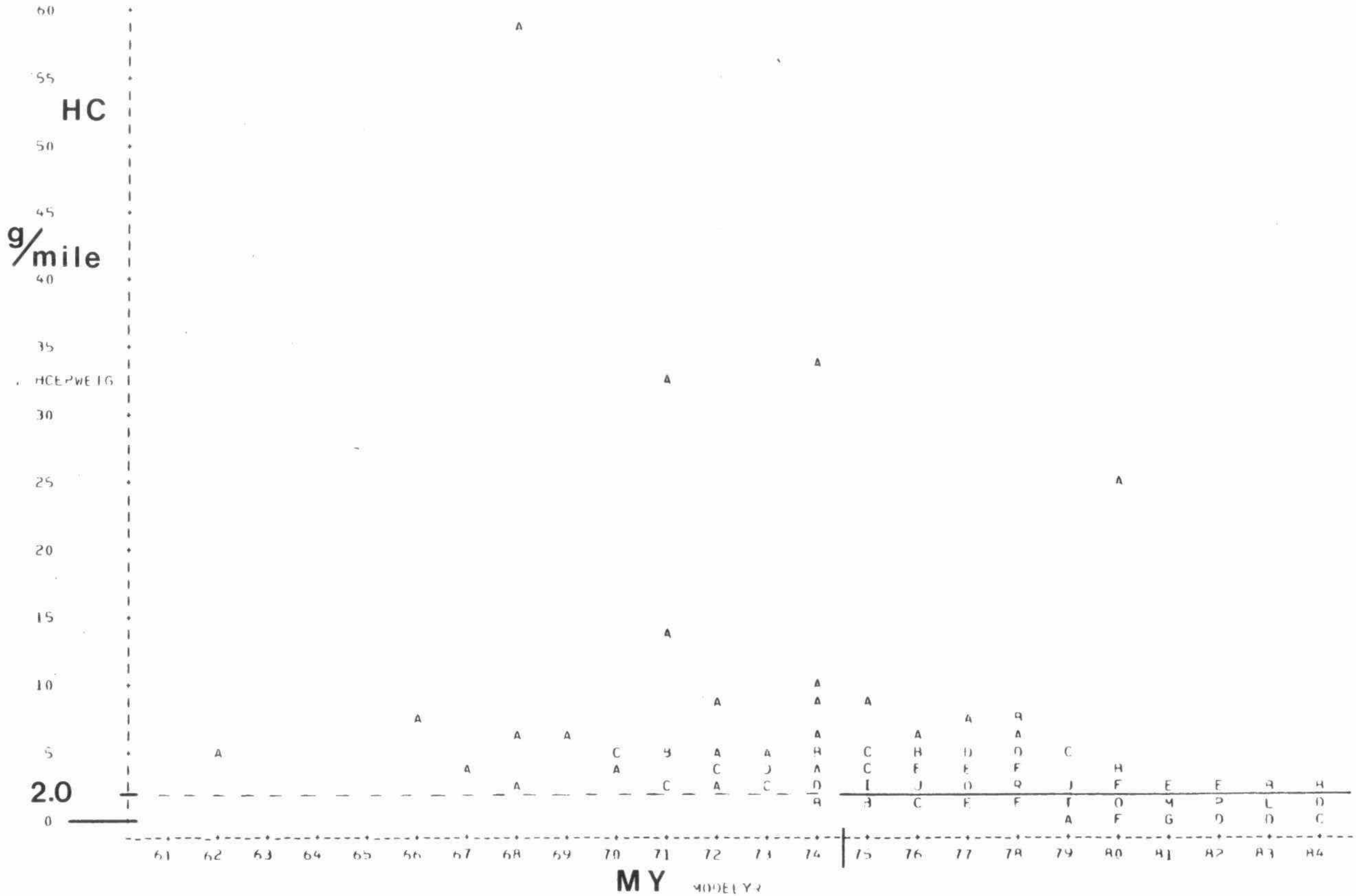
Notes: (1) Canada standards in lock-step with U.S.

(2) Canada standards "frozen" for thirteen years (1975-1987), while U.S. standards became progressively more stringent.

(3) With the 1988 model year Canada standards for HC, CO and NO_x will be tightened up to the U.S. levels.

WIDER ONTARIO SAMPLE - 245 CARS 1
11:52 MONDAY, AUGUST 20, 1984

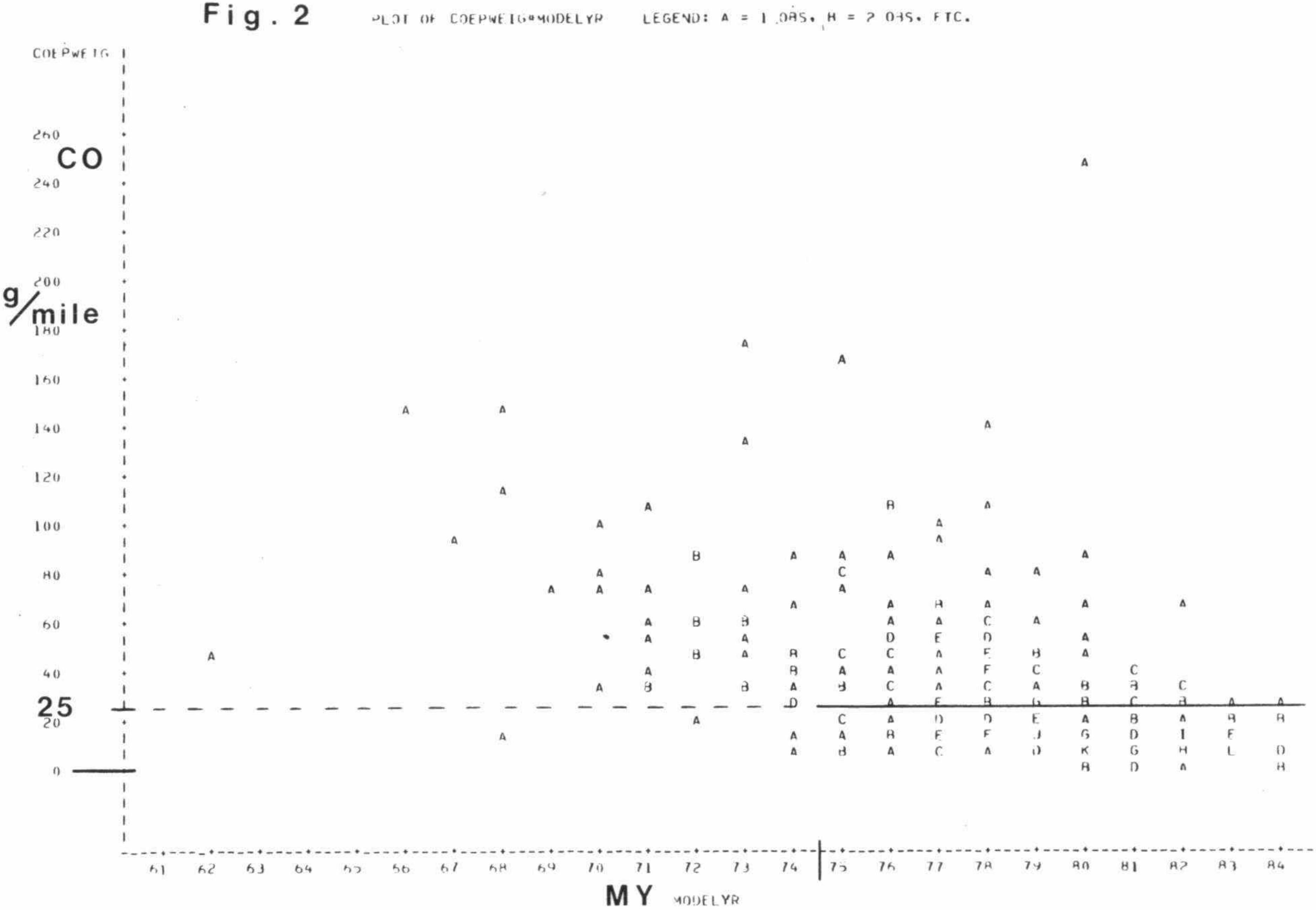
Fig. 1 PLOT OF HCEPWEIG*MODELYR LEGEND: A = 1 OBS, B = 2 OBS, ETC.



NOTE: 4 OBS HAD MISSING VALUES

ATTACH. 2

Fig. 2



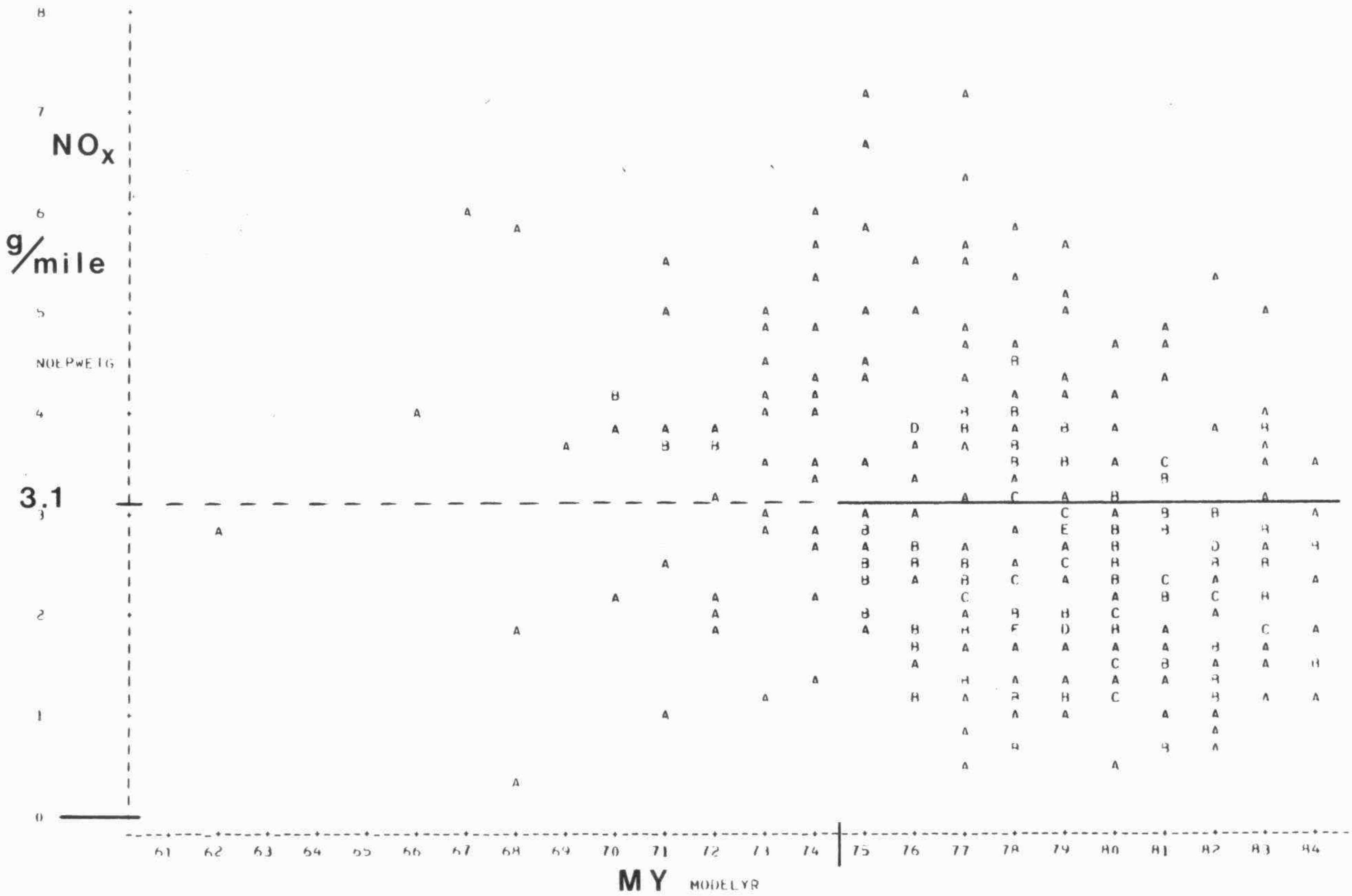
ATTACH. 3

W I D E R   O N T A R I O   S A M P L E - 2 9 5   C A R S

5
11:52 MONDAY, AUGUST 20, 1984

Fig. 3

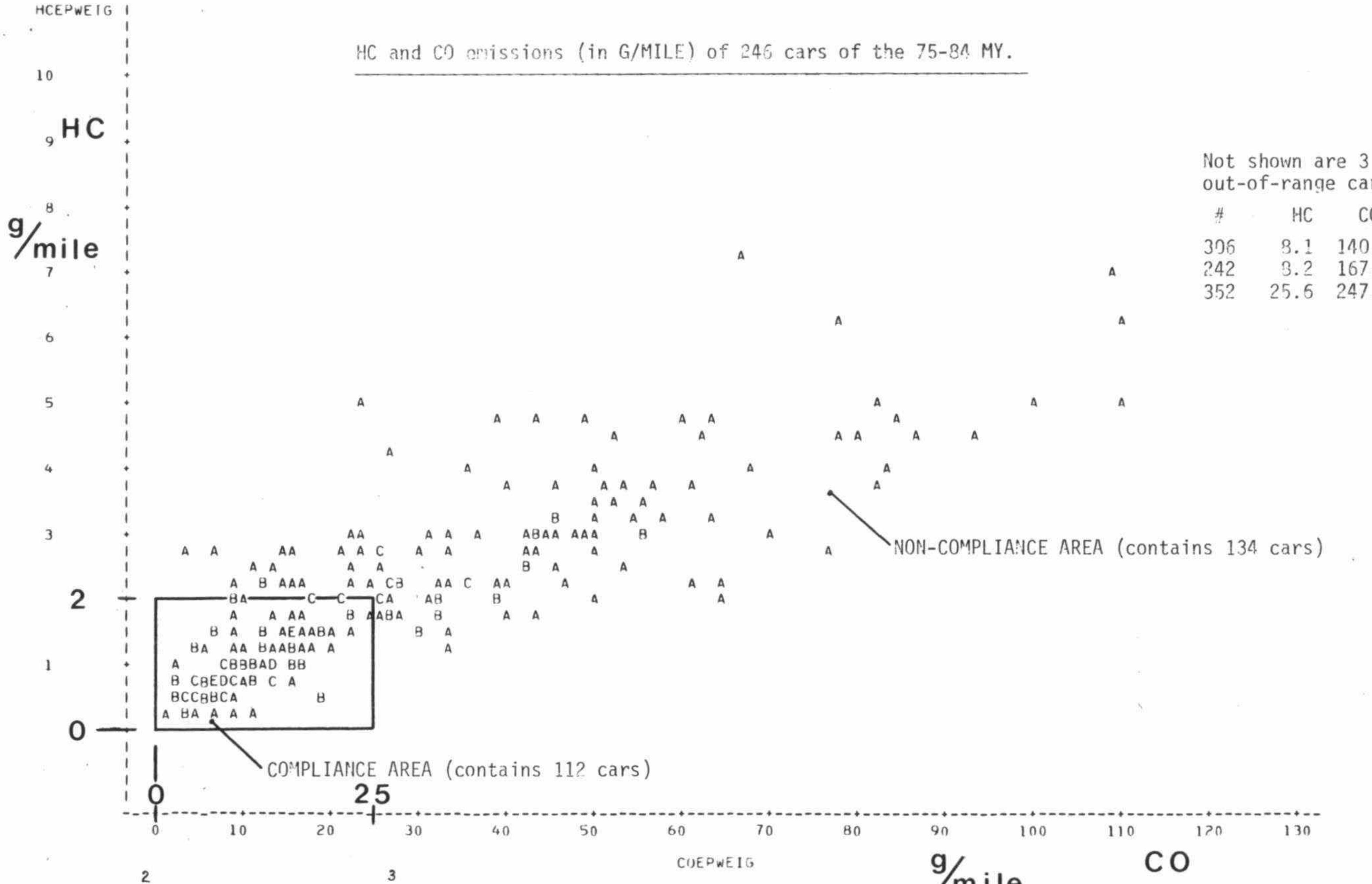
PLOT OF NOEPWEIG*MODELYR   LEGEND: A = 1 OBS, B = 2 OBS, ETC.



WIDER ONTARIO SAMPLE - 295 CARS 2
1975-1984 MODEL YEAR : 248 CARS 14:41 TUESDAY, AUGUST 21, 1984

Fig. 4

PLOT OF HCEPWEIG*COEPWEIG LEGEND: A = 1 OBS, B = 2 OBS, ETC.



ATTACH. 5

NOTE: 2 ~~5~~ OBS HAD MISSING VALUES, 3 ~~07~~ WERE OUT OF RANGE

Table 2

Fleet A (WOS 295) and Fleet B (OS200)
Simple Statistics - Arithm. Means

Model Year	N (Cars)	Mileage (10^3 miles)	EPA Urban Cycle in G/Mile HC	CO	NO_x	Fuel Consump. L/100 km	CO Idle %v.	CO Fast Idle %v.
1	2	3	4	5	6	7	8	9
A) FLEET A (Wider Ontario Sample 295)								
1984	9	5.2	1.3	10.0	2.2	11.7	.4	.4
1983	20	10.4	1.0	10.6	2.7	12.4	.3	.2
1982	25	13.0	1.3	16.5	2.2	11.5	.7	.7
1981	25	13.6	1.1	16.7	2.6	12.2	1.0	.4
1980	30	25.1	2.2	26.9	2.3	13.4	1.2	.3
1979	34	35.3	2.0	24.5	2.8	13.5	1.0	.5
1978	36	48.0	3.1	42.8	2.8	14.0	2.6	.8
1977	30	59.1	3.0	36.2	3.1	15.1	2.3	.6
1976	21	68.3	3.0	47.6	2.8	16.4	3.0	.9
1975	18	72.8	3.3	50.3	3.5	17.4	3.0	1.0
1974	13	73.7	6.5	37.6	3.9	15.4	2.9	1.2
1973	9	73.6	3.5	74.7	3.7	16.0	2.8	1.6
1972	7	98.6	4.5	57.4	2.9	17.2	3.4	1.0
1971	7	117.1	9.2	57.8	3.6	16.7	2.2	1.8
1970	4	146.3	4.7	70.5	3.6	16.0	4.8	1.9
1969	1	52.0	5.8	74.4	3.7	17.3	2.6	1.5
1968	3	120.0	22.9	91.3	2.7	17.2	5.7	2.9
62-67	3	136.7	5.4	94.7	4.2	16.6	5.5	3.9
All	295	46.3	3.0	34.5	2.9	14.2	1.9	.8
B) FLEET B (Ontaro Sample 200)								
All	200	50.4	3.4	39.5	2.9	14.3	2.2	1.0

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